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ANALYSIS OF DEFECTS IN TROUSER MANUFACTURING: DEVELOPMENT OF A KNOWLEDGE-BASED FRAMEWORK

Volume II: FDAS User Manual

Research sponsored by

Defense Logistics Agency
DLA-PRM
Cameron Station
Alexandria, Virginia

DLA Contract #: DLA-900-87-D-0018-0003

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Georgia Tech Project #: E-27-637

November 1988 - November 1991

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EXECUTIVE SUMMARY

Research has been carried out to analyze defects in apparel manufacturing. Two knowledge-based software systems -- FDAS (Fabric Defects Analysis System) and SDAS (Sewing Defects Analysis System) -- have been developed. The research has been funded by the U.S. Defense Logistics Agency under contract number DLA-900-87-D-0018-0003.

FDAS covers the common manufacturing defects occurring in greige and finished fabrics, including those in indigo-dyed denims. SDAS covers the defects occurring in the cutting, sewing, finishing and packing departments of an apparel plant producing denim trousers. Based on the visual description of the defect in the fabric (type, orientation and mode of repetition of the defect), FDAS identifies the defect and suggests possible causes and remedies.

SDAS uses information on the location and nature of the defect to identify the manufacturing operation causing the defect and displays possible causes and remedies for the defect. SDAS also has a provision to display the relevant construction specifications (MIL-SPEC) for the assembly operation causing the defect. Both FDAS and SDAS are implemented in Nexpert Object and are linked to a relational data base using Oracle. They run under both MS-DOS and Unix environments. Software manuals for using FDAS and SDAS have been produced.

FDAS is intended for use at the greige or finished fabric inspection station in a weaving plant. It can also serve as a backend to a vision-based inspection system. SDAS can be used by an apparel plant for the inspection of trousers.

About the Report: The final technical report is presented in three volumes. In Volume I, the details of the research effort are discussed along with recommendations for additional research. Volume II (the present volume) is the software user manual for FDAS, while Volume III is the software user manual for SDAS.

1. INTRODUCTION

1.1 What is FDAS?

FDAS (Fabric Defects Analysis System) is an identification and diagnosis system for defects encountered in woven fabrics. The system covers the common manufacturing defects occurring in greige and finished fabrics, including those in indigo-dyed denims. The development of the system has been funded by the U.S. Defense Logistics Agency.

1.2 Working Principle of FDAS

The flowchart in Figure 1 summarizes the working of FDAS.

First, FDAS assembles information about the current defect, as seen by the user. The user indicates a few salient visual features of the defect such as defect type, orientation, and mode of repetition along warp and filling directions. After receiving information on the visual characteristics of the defect, the software compiles a list of all possible fabric defects that share the particular visual description. The system presents a precise description of each individual defect in this group, and allows the user to decide which description exactly matches the defect under review. This matching of defect description with the actual defect is the final step in the identification process. The software then displays an analysis of the defect by listing the possible causes and remedies.

1.3 Scope and Applications of FDAS

In its present form, FDAS is ideally suited for indigo-dyed denim fabrics. However, the system can be used by any weaving or finishing plant because it has the knowledge for the analysis of defects occurring in these processes. Classification and analysis of defects on a day-to-day basis will be helpful in maximizing the percentage of first quality production. The system can be located at the greige or finished fabric inspection station or at the tenter frame to record and classify defect occurrences on a continuous production basis.

FDAS is linked to a database program; so it can be used to keep track of defect occurrences and initiate remedial action when required, e.g., whenever a particular defect type or the overall percentage of defective products exceeds pre-set threshold levels. Database software will also simplify report generation and quality monitoring of the different fabric sorts and styles in production.

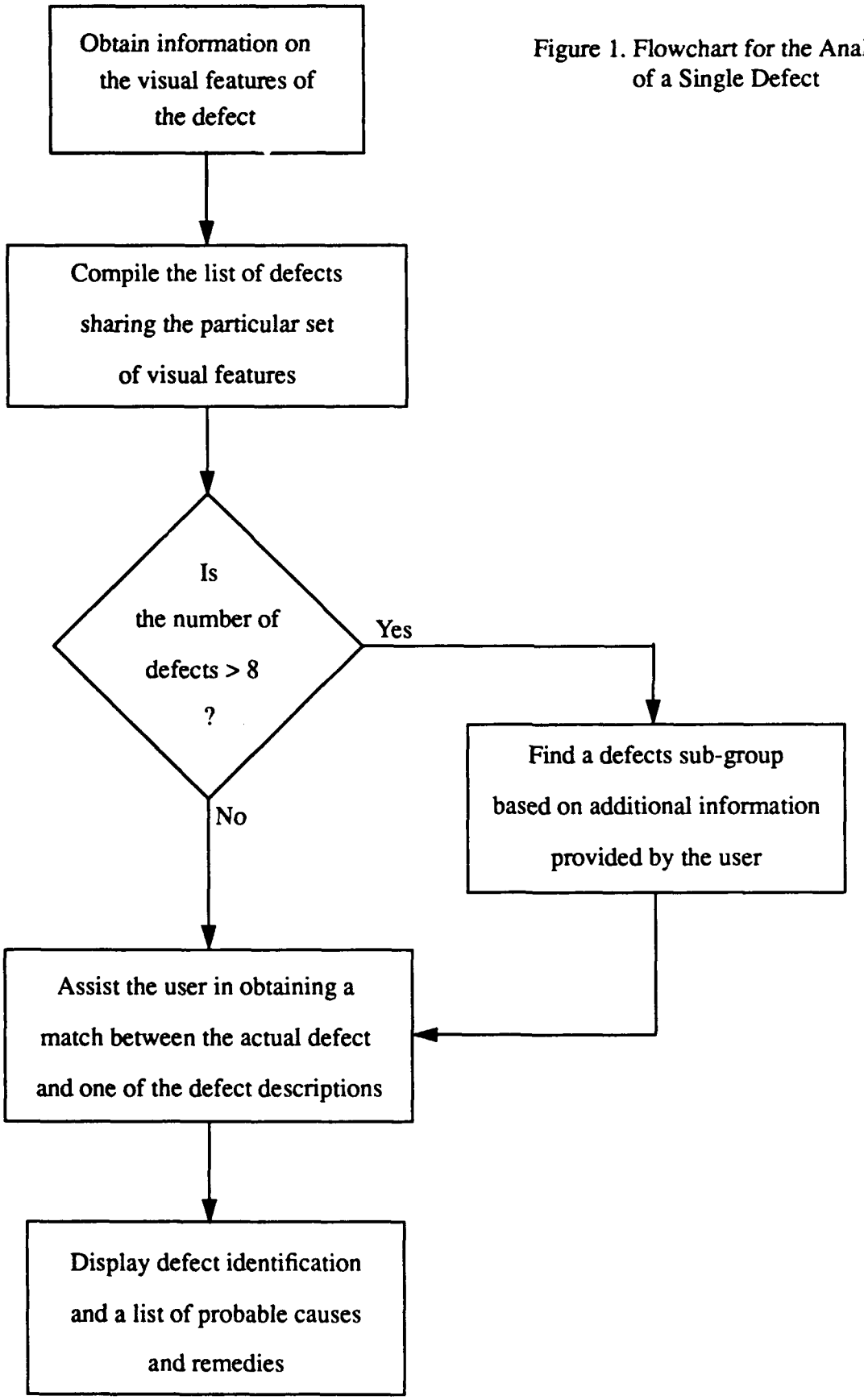

Figure 1. Flowchart for the Analysis of a Single Defect

1.4 Requirements From the User

To make efficient use of FDAS, the user should possess a basic understanding of the system. It is very important to remember that FDAS is an aid for the classification and analysis of fabric defects and not a replacement for a sharp-eyed and experienced inspector.

The learning time depends on the background and education level of the user but is not expected to be more than a day or two at most. An average high school graduate with basic analytical skills and an adequate exposure to the production environment can understand and operate the system without difficulty.

The software is user friendly and is designed to work fast. The design of the system is such that the user spends very little time on the computer and more time on fabric inspection. Classification and analysis of a single defect will take 10-30 seconds, depending on the type of defect being analyzed, and how quickly the user responds to the queries posed by the system.

2. OPERATIONAL DESCRIPTION

The operation of the system involves two major steps:

1) Establishing the sub-group into which the particular defect under review falls, using the visual characteristics of the defect as a guide.

2) Presenting defect descriptions to the user and assisting in finding the closest match between the actual defect and the defect description.

If the user makes a mistake while providing the set of visual characteristics of a defect, the software allows the user to re-start the analysis from the beginning. Also, if the user has problems in finding an exact match for the defect being inspected from the existing descriptions of a particular defect class, the software allows re-specification of all the input (defect description) data.

2.1 Starting Up FDAS

The current version of FDAS records defect data to an Oracle® database. Along with FDAS software, a database file is also provided. The user must ensure that Oracle is running before starting up FDAS.

To start the system, go to the directory "nxpprot\nxpforms\def." Start the defects analysis software by typing "fdas" at the command prompt. FDAS automatically loads the fabric defects knowledge base.

2.2 Defect Analysis

FDAS depends solely on the user's input to correctly identify any particular defect in the fabric. The importance of correct input to the system, based on the actual appearance of the defect, cannot, therefore, be over-emphasized. FDAS seeks and receives information in a step-by-step manner and, at each step, it makes certain decisions based on the current information. At any of the input stages, if the user fails to respond to the FDAS query, it will simply remain there and no further progress is possible. If incorrect or inadequate information is provided, FDAS will issue an error message to help the user correct the failure and continue. The cycles of defect identification, analysis and diagnosis are continuous and automatic, until the user decides to quit FDAS.

2.2.1 Input of defect type

As soon as defect analysis is initiated, the system brings up a question (see Figure 2), asking

for the defect type.

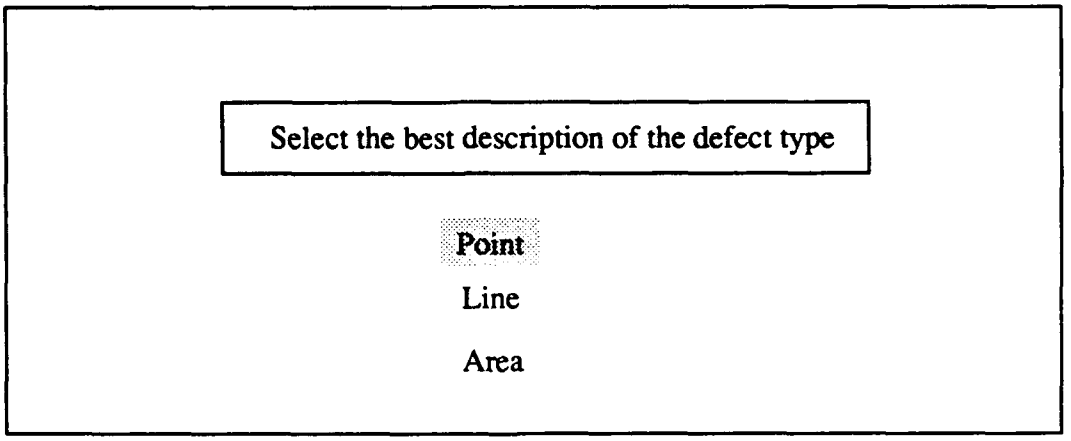

Figure 2. Defect Type Selection Screen

The three possible answers to this question are:

1. **Point:** For tiny point-sized defects, with area or diameter not exceeding that of a cigarette stub.

2. **Line:** For linear defects of thickness not larger than three or four yarn diameters, and length greater than one centimeter.

3. **Area:** For large random-sized defects extending in both warp and filling directions. This category includes area defects of all possible shapes whose area exceeds that of a cigarette stub.

2.2.2 Input of defect direction and extent

After the user indicates the defect type, the software displays further queries as shown in Figure 3 and seeks information on the direction and extent of the defect.

The five possible answers to the direction and extent query are:

1. **Continuously Along Length:** For defects seen running lengthwise (in the warp direction) with an extent of at least 5-6 yards. The length of the defect is, of course, not subject to any upper limit.

2. **Continuously Along Width:** For defects spanning the entire width of the fabric from selvage to selvage.

3. **Partially Along Length:** For defects running lengthwise (in the warp direction) and con-

fined in extent to less than 5-6 yards. The defect terminates after running for a short distance along the length of the fabric.

4. **Partially Along Width:** For defects lying in a widthwise direction (along filling), but not across the entire width.

5. **No Preferred Orientation:** For defects whose orientation is not along either of the two principal fabric directions. Some examples of defects exhibiting random orientation are splotches and stains.

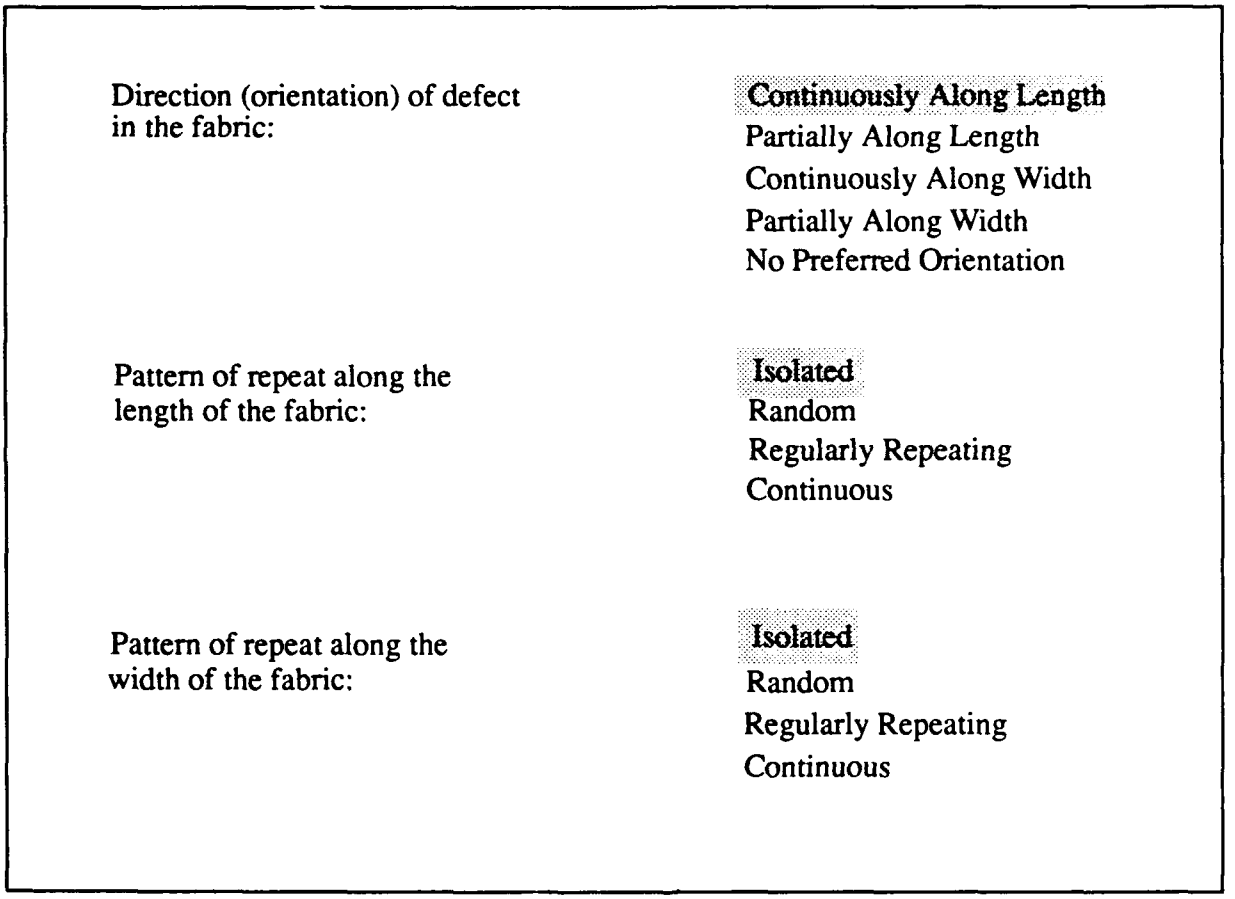

Figure 3. Screen for Indicating Defect Direction and Pattern of Lengthwise, Widthwise Repetition

2.2.3 Input of lengthwise repeat pattern

In the next step, the System retains the screen (displayed above in Figure 3) and expects the user to define the repeat mode in the lengthwise direction.

The possible choices for lengthwise repeution are:

1. **Continuous:** The defect extends continuously along the lengthwise direction (i.e., warp) of the fabric. It must be noted that if "Continuously Along Length" has already been chosen as the directional characteristic, then only this choice is appropriate for the repeat pattern.

2. **Isolated:** The defect occurs just once in the lengthwise direction and then does not recur for a considerable length.

3. **Random:** The defect shows a randomly recurring nature, along the lengthwise direction (i.e., the defect occurs a few times along the warp with no regular repeat pattern).

4. **Regularly Repeating:** The defect repeats at regular intervals along the length.It is not continuous because it is regularly broken-up in the lengthwise direction. It is not random because there is a definite repeat pattern.

2.2.4 Input of widthwise repeat pattern

After receiving input on the lengthwise repeat pattern, the System keeps the display screen shown in Figure 3 and expects the user to specify the repeat mode in the widthwise direction. The four choices possible here are similar to those listed for lengthwise direction.

1 **Continuous:** If the defect extends continuously along the filling from selvage to selvage. Note that if "Continuously Along Width" has already been chosen as the directional characteristic, only this choice is appropriate for the widthwise pattern of repeat.

2. **Isolated:** The defect occurs just once in the widthwise direction and then disappears.

3. **Random:** The defect shows a randomly recurring nature across the width (i.e., the defect occurs a few times across the width with no regular repeating pattern).

4. **Regularly Repeating:** The defect repeats at regular intervals across the width. It is not "Continuous" because the occurrence is broken up at regular intervals. It is not "Random" because there is a definite repeating pattern.

2.2.5 Identification of Defect

The software now identifies the group of defects pinpointed by the visual characteristics of the defect supplied by the user. There may be any number of different individual defects sharing these common visual characteristics. The software identifies all these possible defects which share the particular visual description.

The system's next task is to narrow down the different choices in this category, with the help of the user. If the defect category contains less than eight defects, the user is then presented with a precise description of each individual defect, starting with the first defect in the group. Identification is complete when the user matches the defect with one of the defect descriptions.

If the visual description supplied by the user is shared by more than eight defects, a further subclassification of defects falling under the group is necessary. Such a subclassification reduces the diagnosis time by minimizing the number of defect descriptions presented to the user to choose from. Typical choices of subclassification for one of the crowded groups are shown in Figure 4.

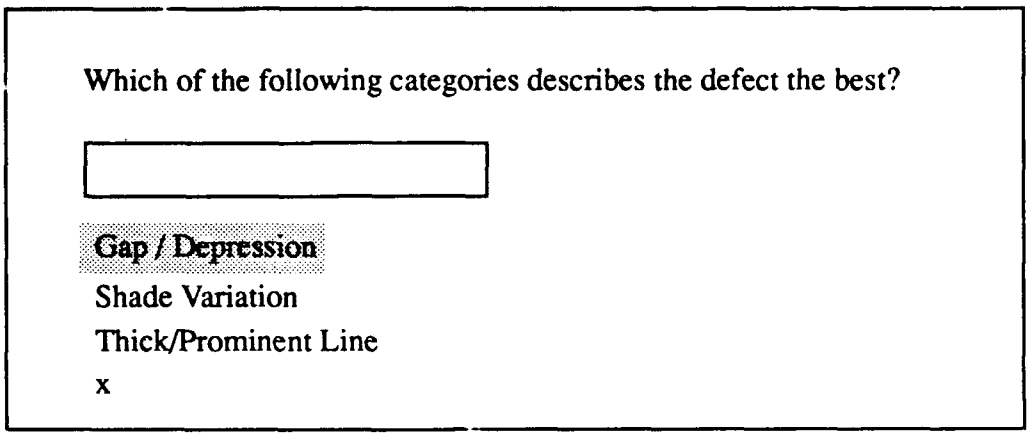

Figure 4. Typical subclassifications for a Line Defect category

For example, in Figure 4 each of the features is used to divide the large parent classification into smaller categories. Each of these smaller sets of defects will share the particular common feature indicated by the user.

Once the set of relevant defects is of manageable size, the process of presenting individual defect descriptions for the user to choose from is the same as before. After the defect is precisely identified, the system displays the probable causes of the particular defect. A list of suggested remedies is also presented.

2.3 Diagnosis Capability of the System

The system contains general information on the causes and remedial measures for individual defects in woven fabrics. The System also contains information pertaining to manufacturing technologies such as Open-end Spinning and Air-jet Weaving. Also, the present version of the software includes knowledge for the analysis of fabric defects arising from the indigo-dyeing process.

FDAS, however, is not equipped with knowledge for the analysis of special defects that are characteristic of different brand-name products, process variations, modifications to the production machinery, etc., which may be specific to manufacturing plants or organizations.

The diagnosis information for the whole range of defects is available in the "causes" subdirectory on the computer. The same files are used by the software for providing a detailed causes and remedies analysis, once a particular defect has been identified. These diagnosis files may be

accessed and modified to suit the needs of individual process conditions and manufacturing technologies. FDAS can thus be customized to meet special demands and needs of an organization.

3. SAMPLE SESSIONS

In this section, three typical denim fabric (3/1 twill weave) defects are described, one of each defect type: Point, Line, and Area. Typical interactive screens presented to the user during each defect identification and diagnosis session are also shown.

3.1 Point Defect

For illustration purposes, we have chosen a very simple example of a point defect. Let us assume that the inspector observes a small hole in the fabric, about 1/4" in diameter, with brown edges. This occurs only at one place on the fabric, and then does not appear again.

When the inspector begins the session, the screen shown in Figure 5 is displayed. The inspector selects the type of defect from this screen, by moving up or down between the three choices using the up- and down-arrow keys. To indicate a choice, the inspector moves to the appropriate defect type and presses the <Enter> key.

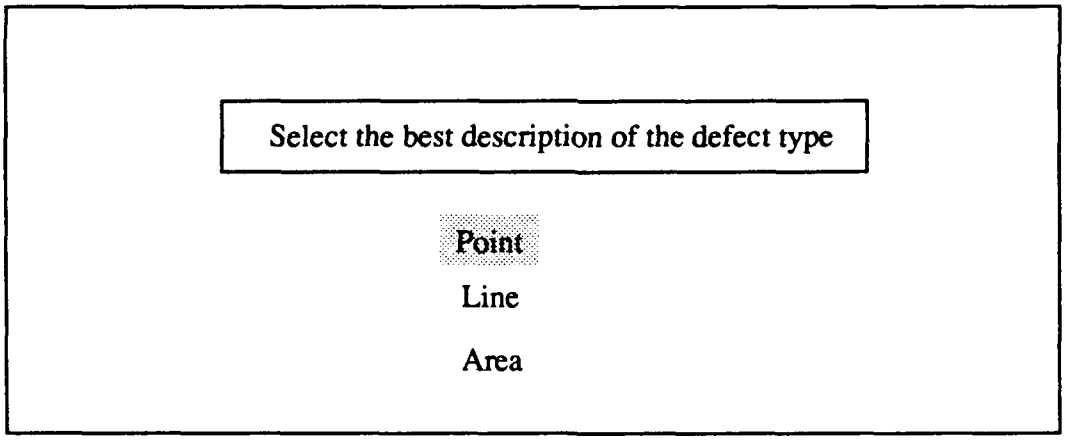

Figure 5. Defect Type Selection Screen

At this point, the second screen (Figure 6) is displayed to enable the inspector to make selections for the defect's visual characteristics: direction, lengthwise pattern and widthwise pattern. The up- and down-arrow keys can be used to cycle up and down through the alternatives for the Direction of the defect, until one of these is chosen by the user.

In the current case, the inspector sees a small hole in the fabric, which has no preferred orientation as far as the fabric's length and width are concerned. Hence the most appropriate choice would be "No Preferred Orientation". The user goes to this choice with the help of the arrow keys,

and presses <Enter>. The choice made for the Directional characteristic of the defect remains highlighted in a different color. At this point the screen will look as shown below:

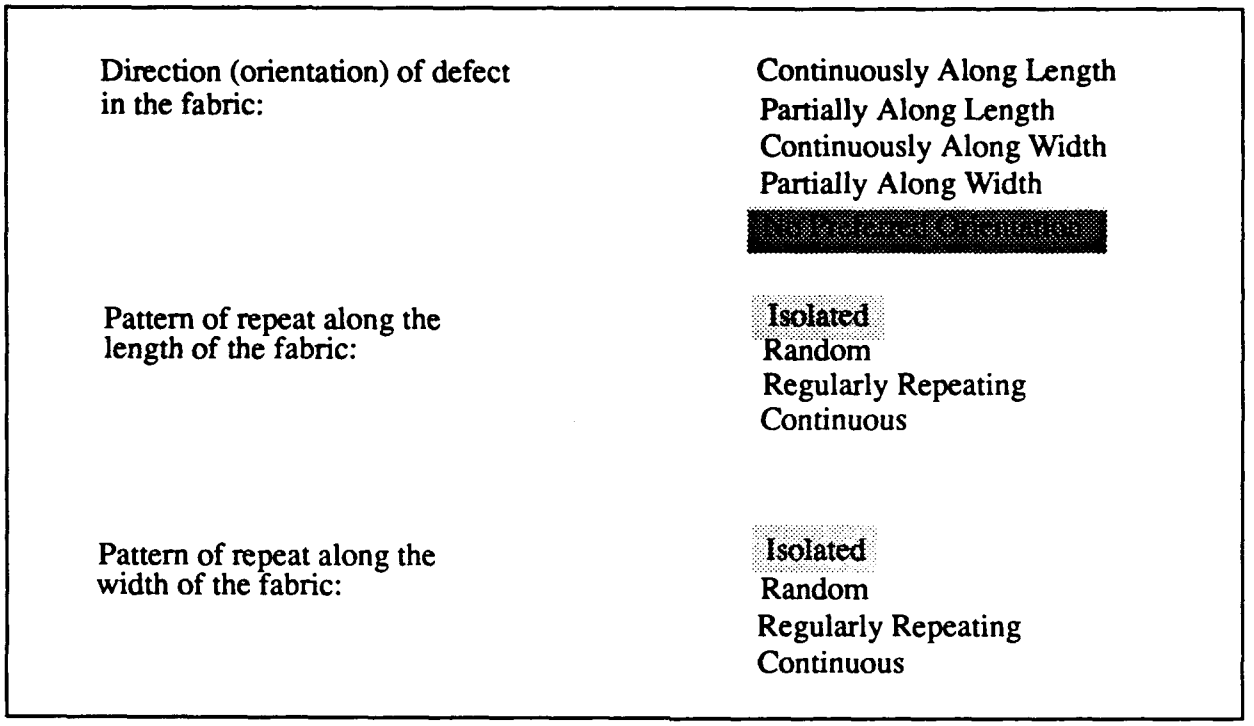

Figure 6. Screen for the Selection of Defect Direction

The inspector can now proceed to the choices for the Pattern of Repeat in the Lengthwise Direction. The arrow keys can be used to move up and down through the four items on this list: 'Isolated', 'Random', 'Regularly Repeating' and 'Continuous'. The inspector makes a choice by pressing <Enter> on the most suitable repeat pattern ('Isolated' in the present case). 'Isolated' remains highlighted as shown in Figure 7.

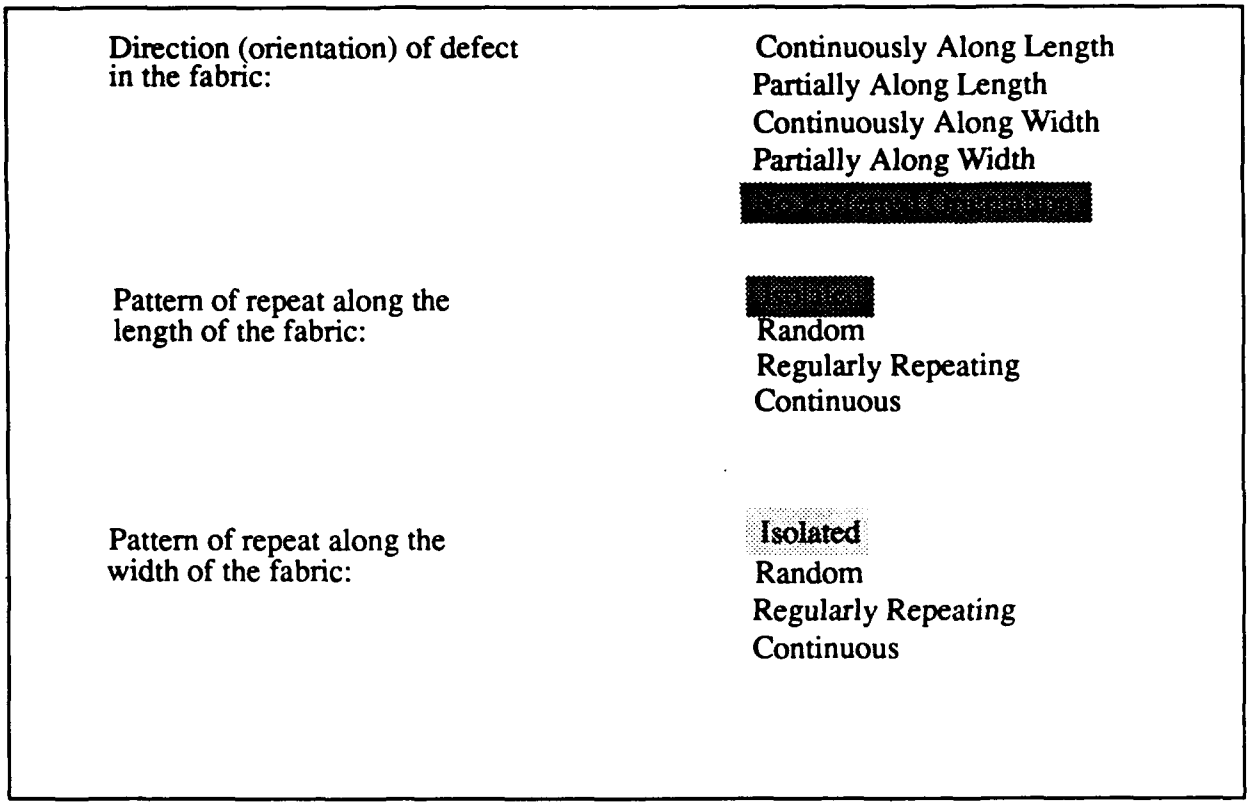

Figure 7. Screen for the Selection of Lengthwise Pattern

The next visual characteristic to be indicated is the Pattern of Repeat in the Widthwise Direction. Again, the 'Isolated' option appears most suitable in the current case, since there is only one small hole and no repeating pattern across the fabric. Upon selecting 'Isolated' and pressing <Enter>, the screen appears briefly as shown in Figure 8, before disappearing. This indicates successful completion of the task of supplying the defect's visual characteristics to the System.

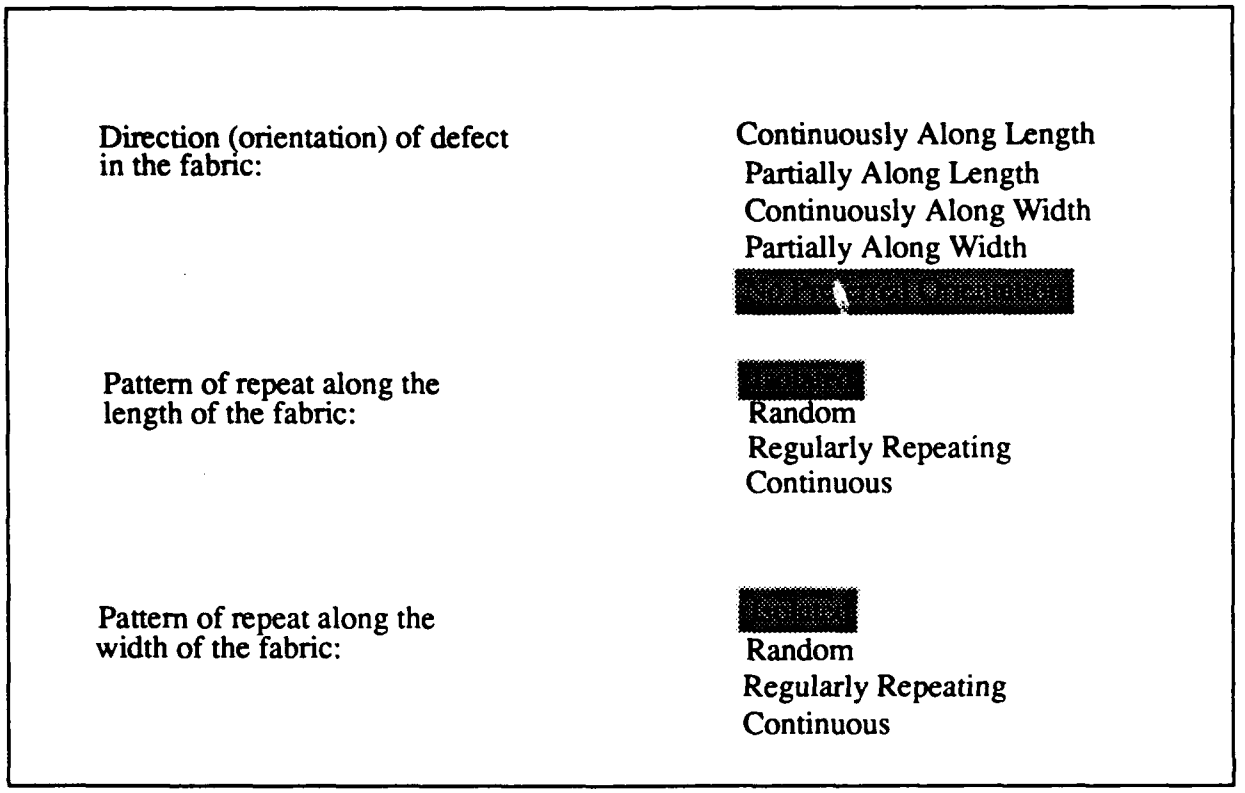

Figure 8. Screen for the Selection of Widthwise Pattern

The software now identifies the defects class characterized by the visual indications provided by the inspector. In the next step, the system identifies the individual defects which are members of this class of defects and presents the inspector with each defect description, one at a time. The inspector must now see if one of these defect descriptions matches the fabric defect being inspected. In the current case, the first defect description that is presented to the user is shown in Figure 9.

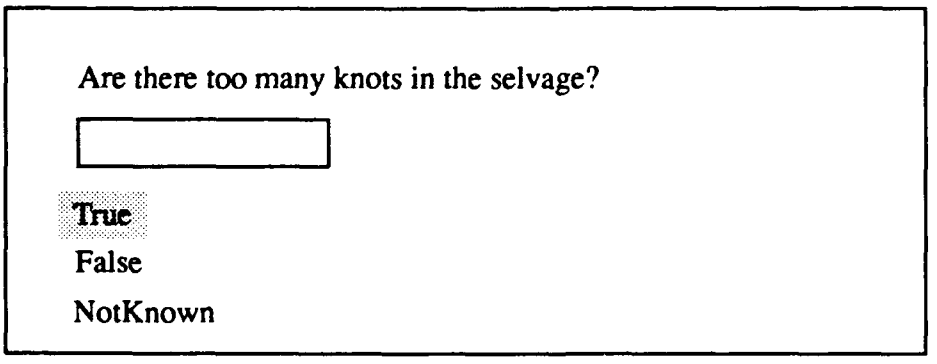

Figure 9. First Defect Description out of Point Defect Category

As before, the arrow keys are used to select one of these options. In this case, selvage knots are not the problem being observed in the fabric, so 'False' is chosen, and the inspector presses <Enter>. The choice appears highlighted in the selection box on screen, and another <Enter> confirms this choice to the System. The screen disappears. Another selection box bearing the next defect description appears as shown in Figure 10.

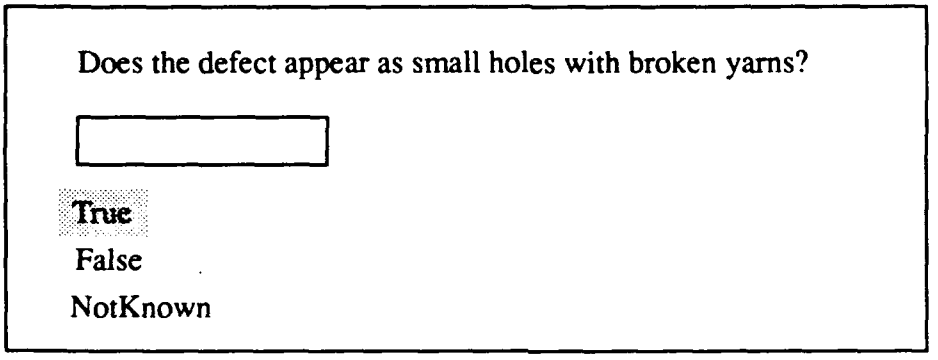

Figure 10. Second Defect Description out of this Point Defect Category

This defect description, too, does not match what the inspector sees in the fabric -- a hole but without broken yarns around the hole. The inspector uses the arrow keys to go to the 'False' option, and confirms the selection by pressing <Enter> twice. The next description reads as shown in Figure 11.:

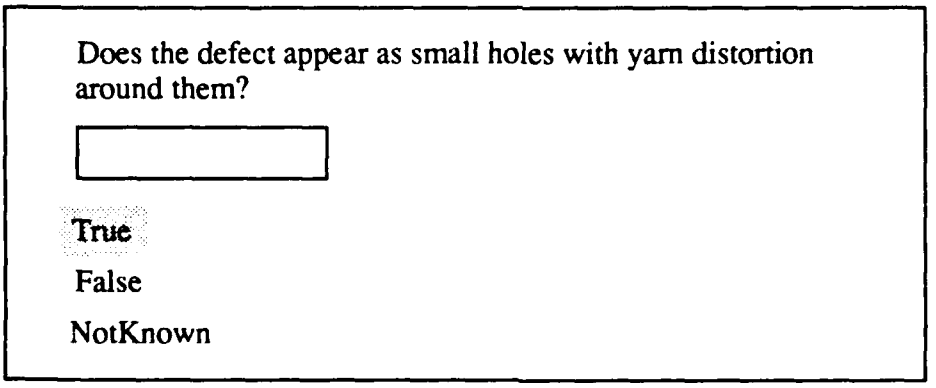

Figure 11. Third Defect Description out of Point Defect Category

The answer is, again, 'False'. When this screen disappears, the next defect description is exactly the same as the appearance of the defect on the fabric (Figure 12):

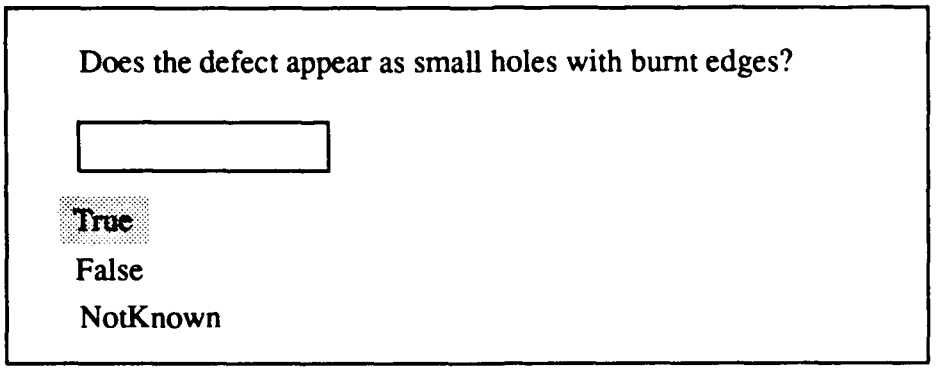

Figure 12. Fourth (and Precisely Matching) Defect Description from Point Defect Category

In this case, 'True' is chosen. As soon as the inspector indicates that the System's defect description matches the actual fabric defect, FDAS identifies the defect as Burnt Holes. The plausible causes and remedies identified by the system are shown in Figure 13.

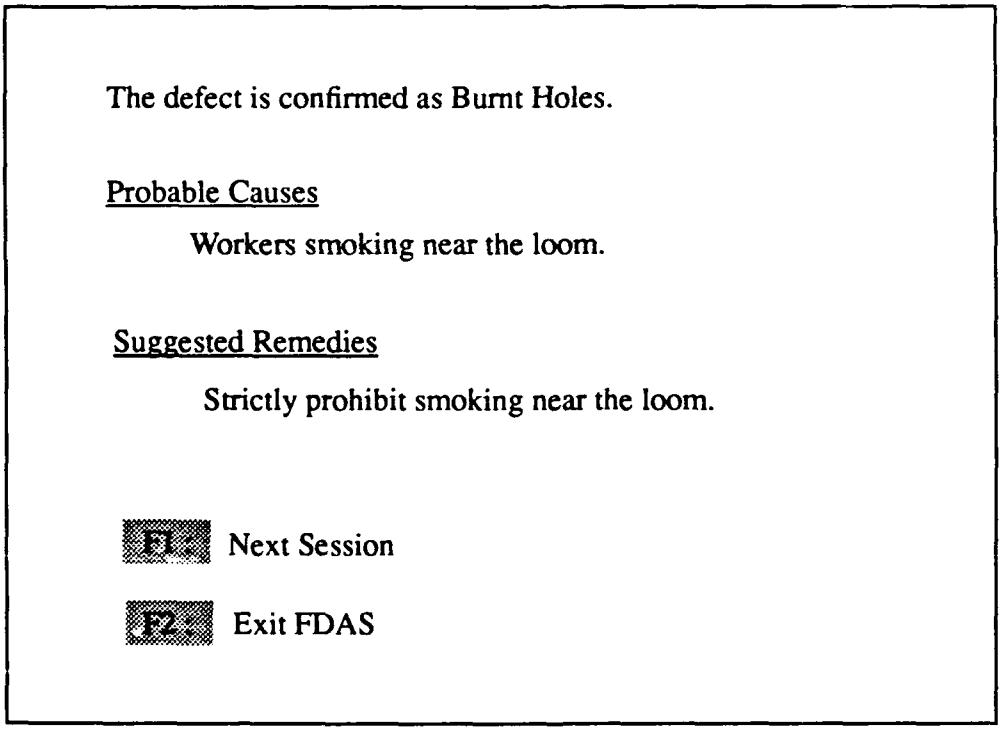

Figure 13. Defect Diagnosis Display

The F1 key clears the diagnosis screen, and re-starts the diagnosis session. The inspector can thus identify and diagnose any number of defects, one after another. The F2 key allows the fabric inspector to exit FDAS, after a consultation session.

3.2 Line Defect

For our second example, let us assume that the inspector observes a single thick and raised line running along the length of the fabric. This is observed at only one place across the width of the cloth.

As before, the inspector begins the session by selecting the type of defect from the first screen. To indicate a choice, the inspector moves to 'Line', which is the appropriate defect type. The first panel looks as in Figure 14.

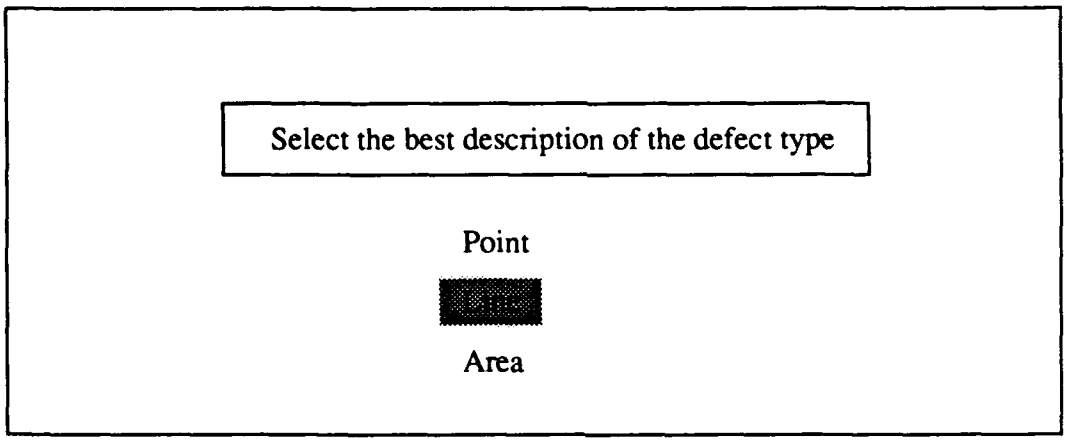

Figure 14. Defect Type Selection Screen

The second screen displays all the choices for the defect's visual characteristics such as direction, lengthwise pattern and widthwise pattern. The inspector makes a selection first for the direction or orientation of the defect, using the up- and down-arrow keys to cycle up and down through the alternatives. Since the inspector sees a single long line running down the length of the fabric, the best choice would be 'Continuously Along Length'. The inspector goes to this choice, and presses<Enter>. This choice remains highlighted as shown in Figure 15.

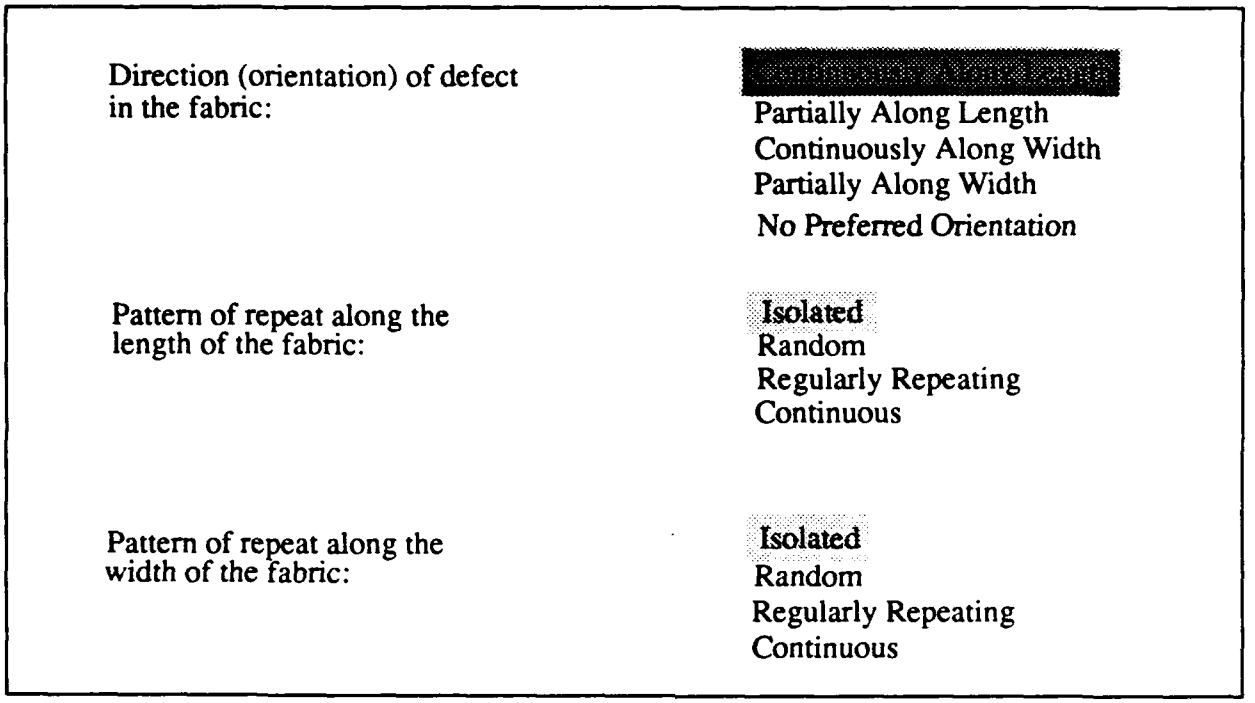

Figure 15. Screen for the Selection of Defect Direction

The inspector selects 'Continuous' from among the choices for the Pattern of Repeat in the Lengthwise Direction (Figure 16). This is the only appropriate alternative, since the defect direction has already been specified as extending along the length of the fabric. Once this choice is made by pressing <Enter>, it remains highlighted.

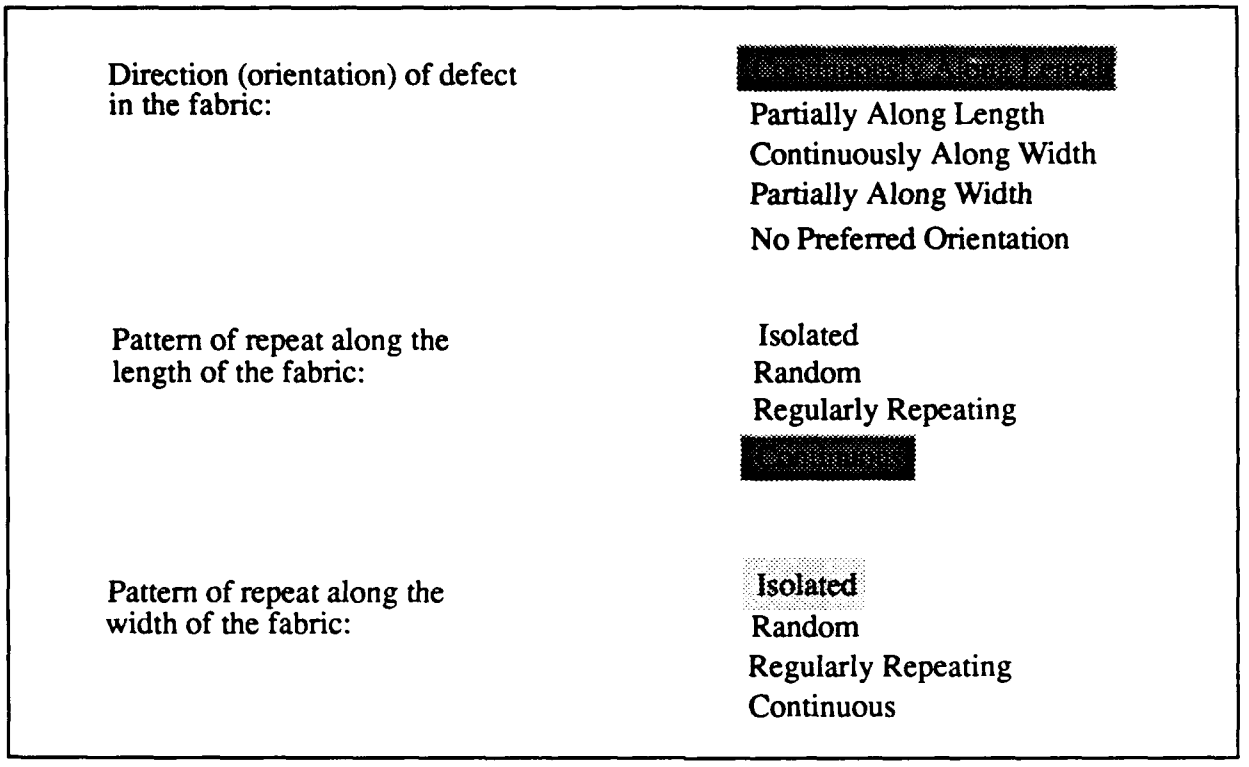

Figure 16. Screen for the Selection of Lengthwise Pattern

Finally, the inspector must make a choice for the Pattern of Repeat in the Widthwise Direction. The 'Isolated' option appears most suitable in the current case, since there is only a single defective line running lengthwise, with no more occurrences or repeating pattern across the fabric. Upon selecting 'Isolated' with the arrow keys and pressing <Enter>, the screen will briefly appear as shown in Figure 17.

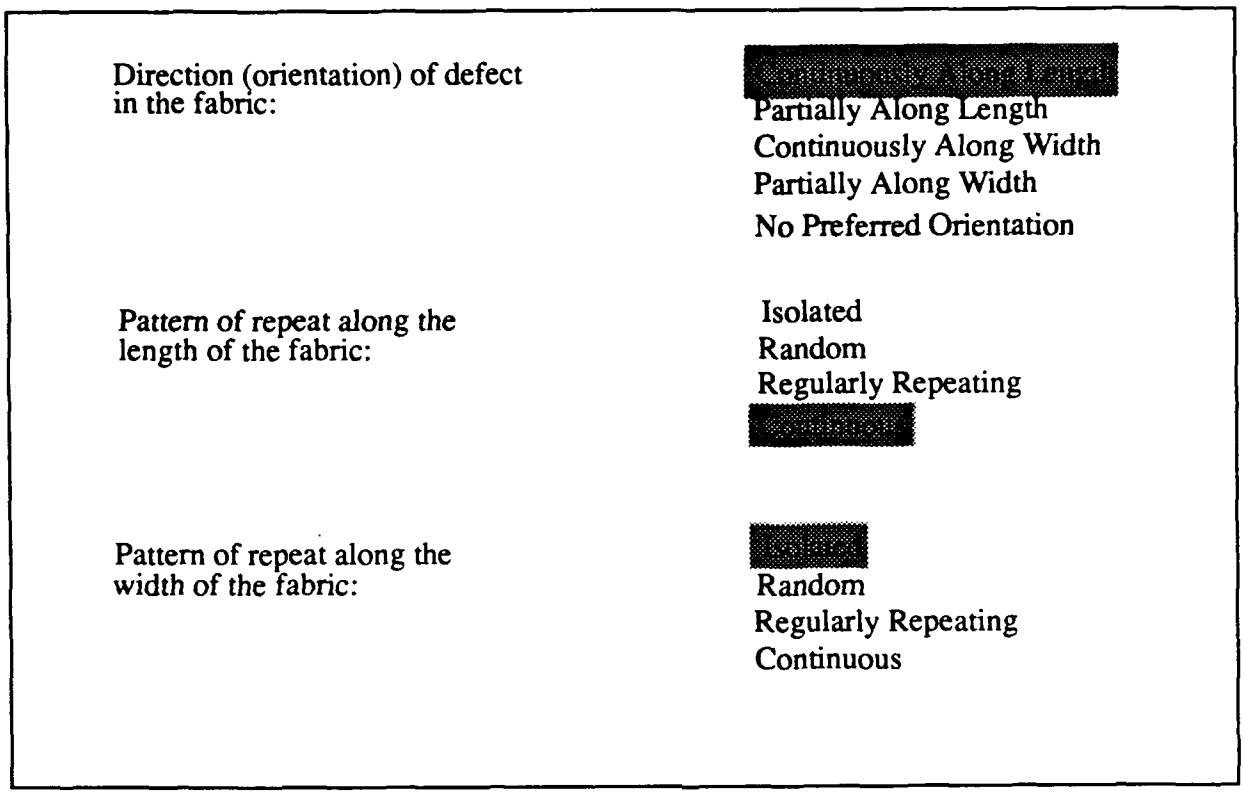

Figure 17. Screen for the Selection of Widthwise Pattern

The system now has a complete set of visual characteristics of this defect. This set denotes a group or category of defects, with every defect in this group sharing this general set of classification parameters.

In the present case, a large number of defects share the visual characteristics that mark this category. Consequently, the system presents the inspector with a further choice from among four sub-categories of defects (as shown in Figure 18) instead of starting to go through a set of individual defect descriptions.

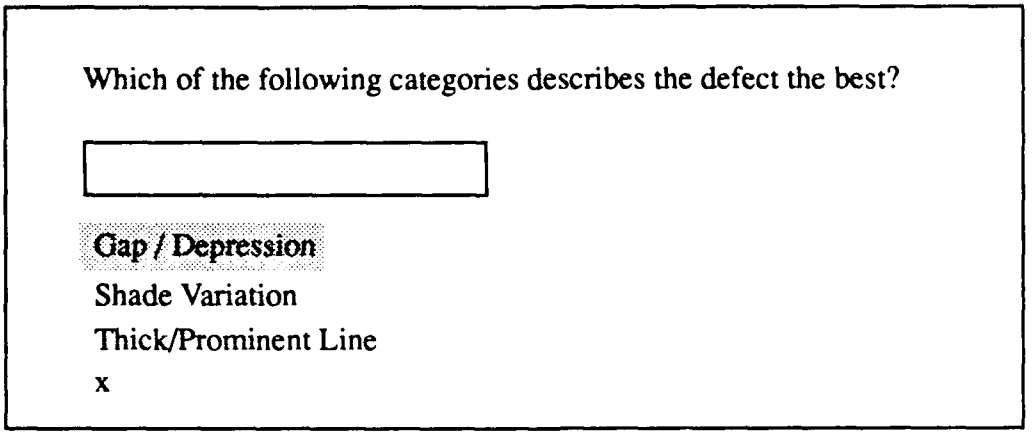

Figure 18. Defect Sub-Categories for Line Defect Category

For the current defect, the appropriate category would be Thick/Prominent Line. Now, the computer will pinpoint all the defects which belong to the category 'Thick/Prominent Line', and the inspector will be presented with only these defect descriptions.

Now FDAS begins with the first defect description, by displaying the screen shown in Figure 19.

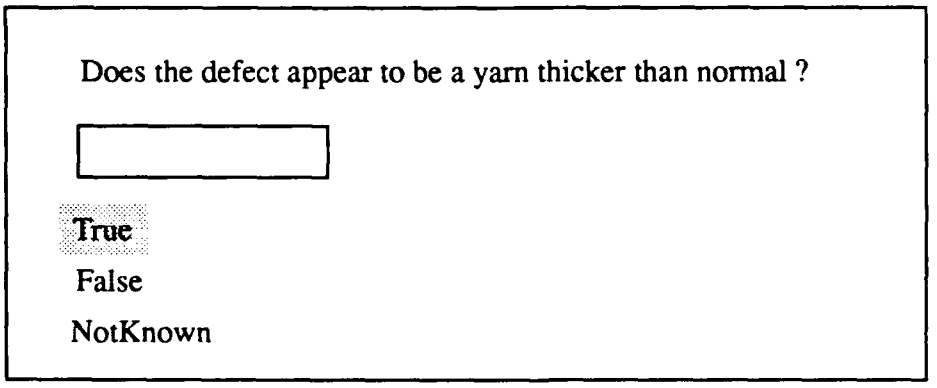

Figure 19. First Defect Description of Thick/Prominent Line Sub-Category

Let us say the inspector examines the fabric and finds that, while this defect description is fairly close, the yarns at the site of the defect are quite normal in diameter. Thus the problem is really something else, and the inspector chooses to select the 'False' option with the arrow keys, followed by <Enter>. This enters the user's choice in the selection box. A second <Enter> confirms this choice to FDAS. FDAS then discards that defect as a valid choice, and displays the next defect description, shown in Figure 20.

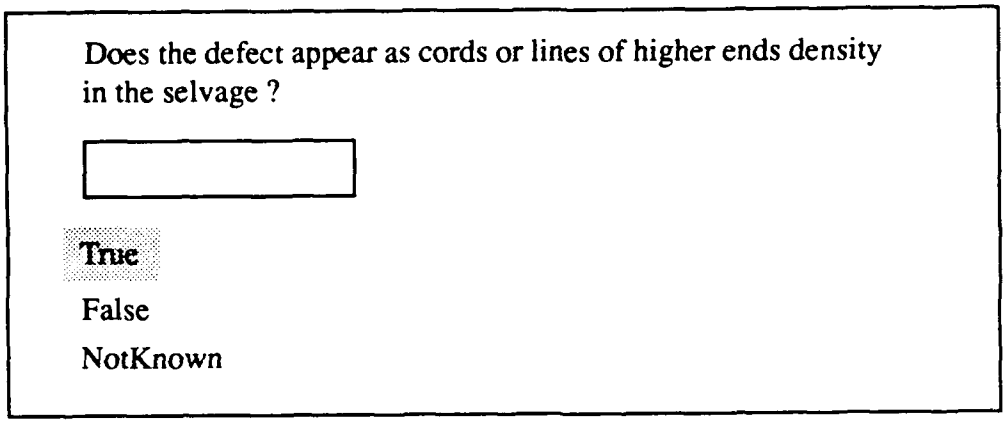

Figure 20. Second Defect Description from Thick/Prominent Line Sub-Category

On inspecting the fabric, the inspector does not find any increase in density of warp yarns around the area of the defect. So, 'False' is chosen. The system proceeds to put up the next defect description for the user's review (Figure 21).

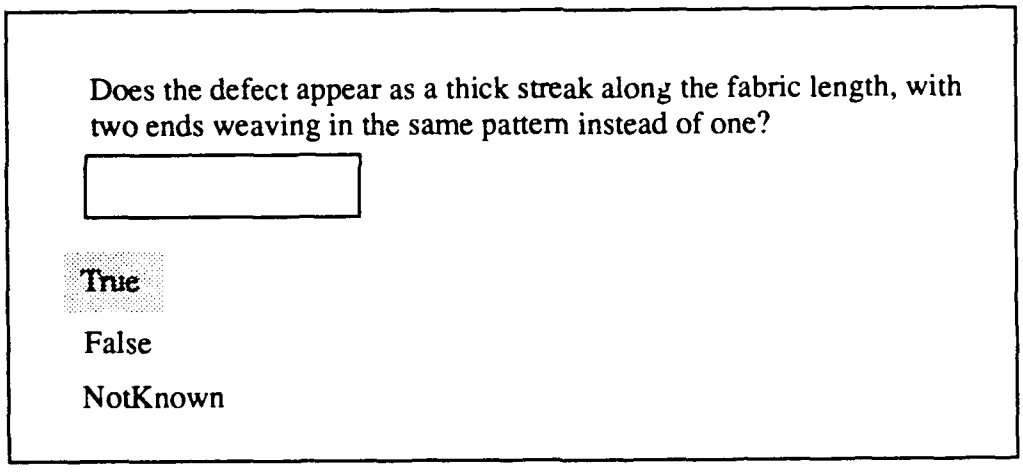

Figure 21. Third Defect Description from Thick/Prominent Line Sub-Category

The inspector finds that this defect description does indeed match what is seen on the fabric. The fabric defect does have two neighboring warp yarns weaving together, which is a defect since it is a twill weave fabric. The user selects 'True'. FDAS identifies this defect as a Double End. Finally it displays an analysis of the causes of the defect, and suggests remedies (Figure 22).

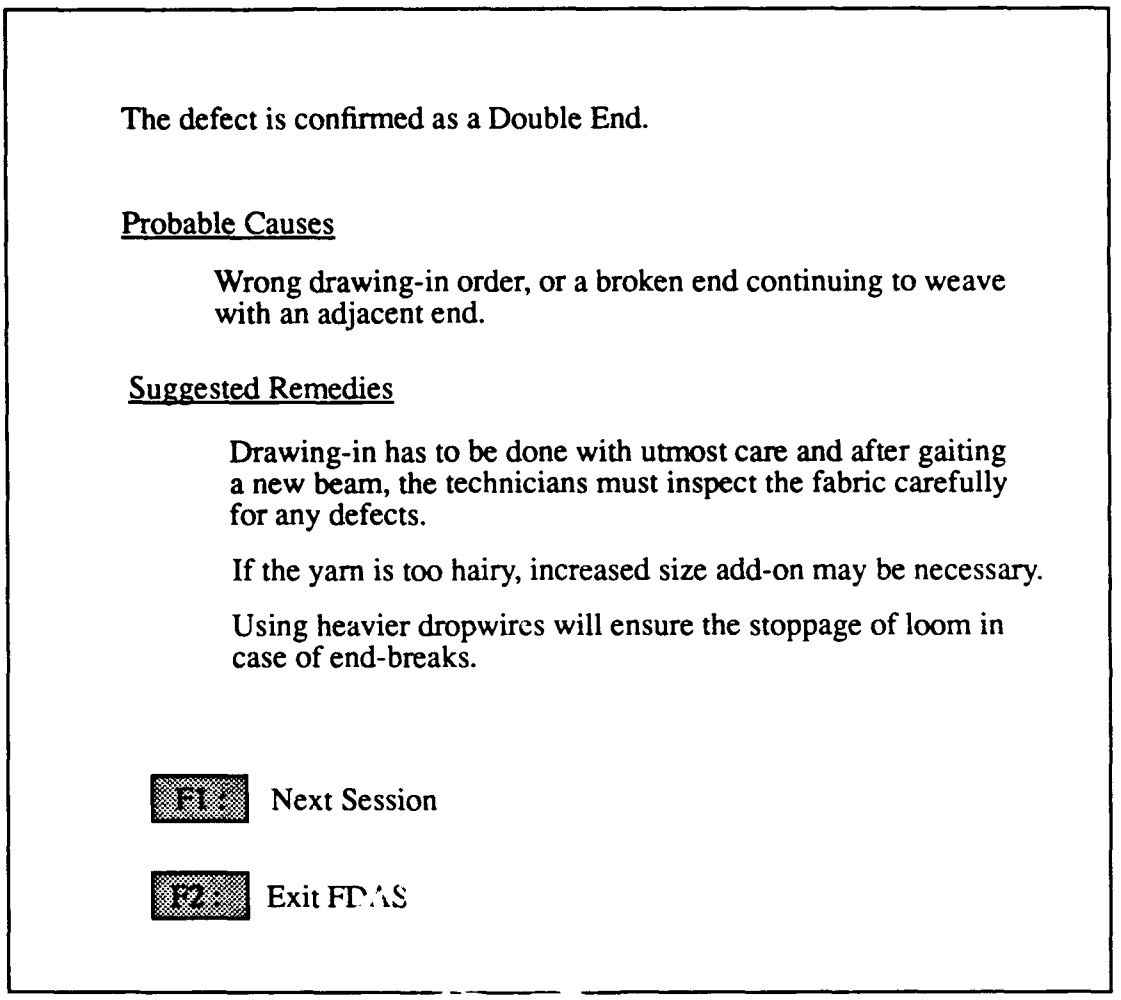

Figure 22. Diagnosis Screen for the Double End Defect

3.3 Area Defect

Assume that the inspector observes a small area in the fabric where the lengthwise (warp) threads appear stretched and a number of knots are present in the warp threads. Also assume this defect is observed only once in the entire piece of fabric being inspected.

The choices made by the inspector to correctly describe this defect are shown highlighted in Figures 23 and 24. The method of making selections from a menu presented to the inspector has been described in the previous two examples.

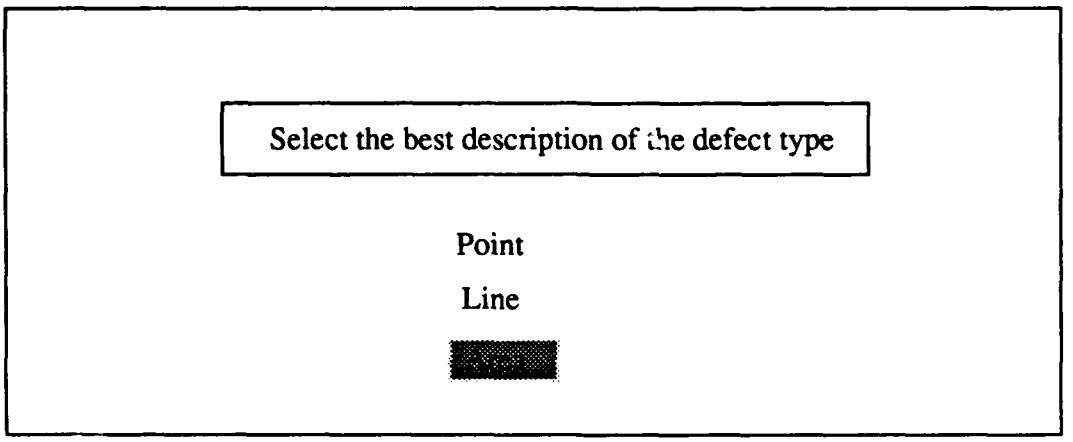

Figure 23. Defect Type Selection Screen

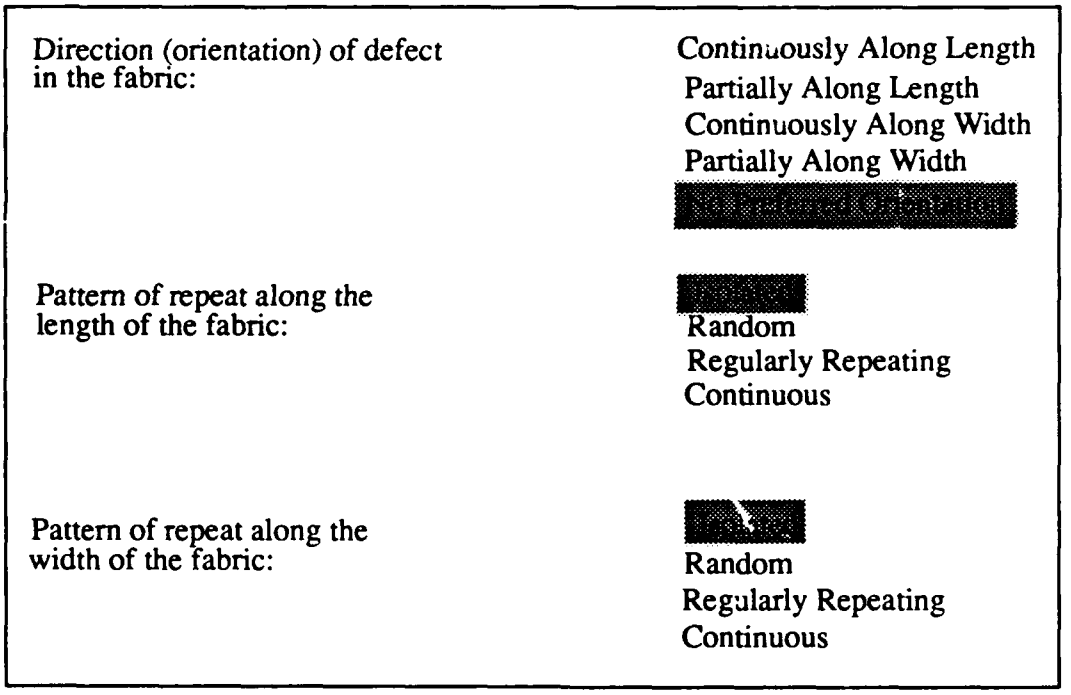

Figure 24. Screen for the Selection of Defect Direction

The system now identifies the defect category based on all these visual indications. Since more than eight defects belong to this category, they are further classified based on their nature. For this, the system presents the screen shown in Figure 25.

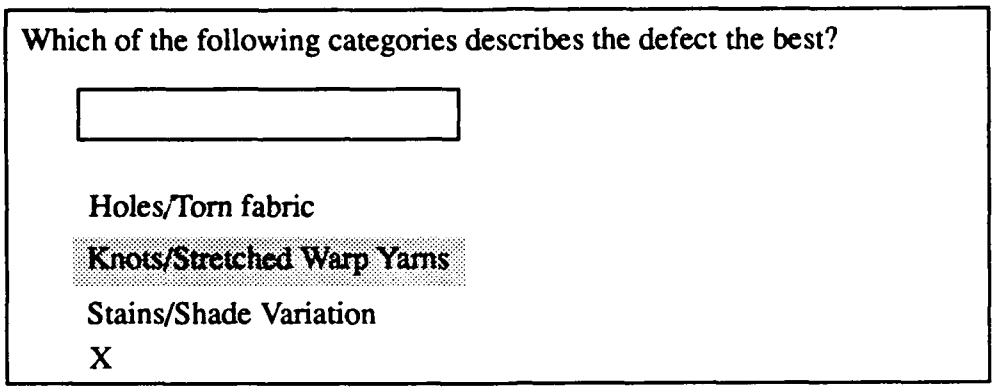

Figure 25. Defect Sub-Categories for this Area Defect Category

The observed defect falls best into the sub-category "Knots/Stretched Warp Yarns". Upon selection of "Knots/Stretched Yarns", the system starts presenting the exact descriptions of individual defects as before. In this case, the first description presented to the inspector describes the defect correctly:

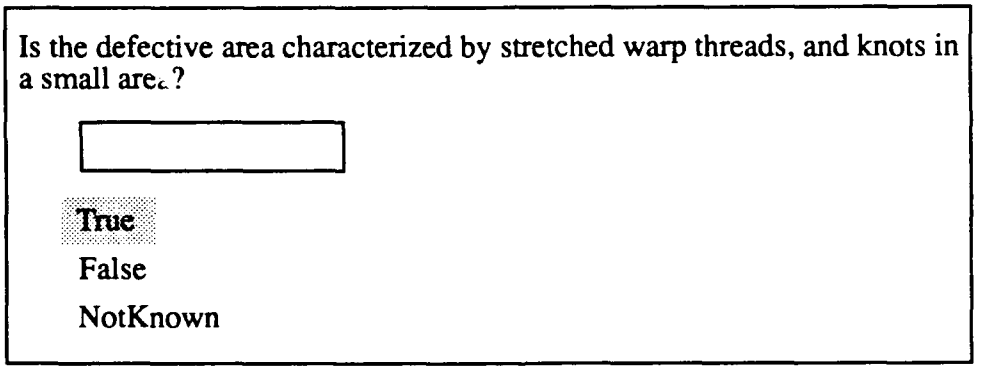

Figure 26. First Defect Description for this Knots/Stretched Warp Yarns Sub-Category

When the inspector confirms the description in Figure 26 as matching the defect observed on the fabric by pressing <Enter>, FDAS displays the window in Figure 27 showing the identity of the defect, its probable causes and suggested remedies.

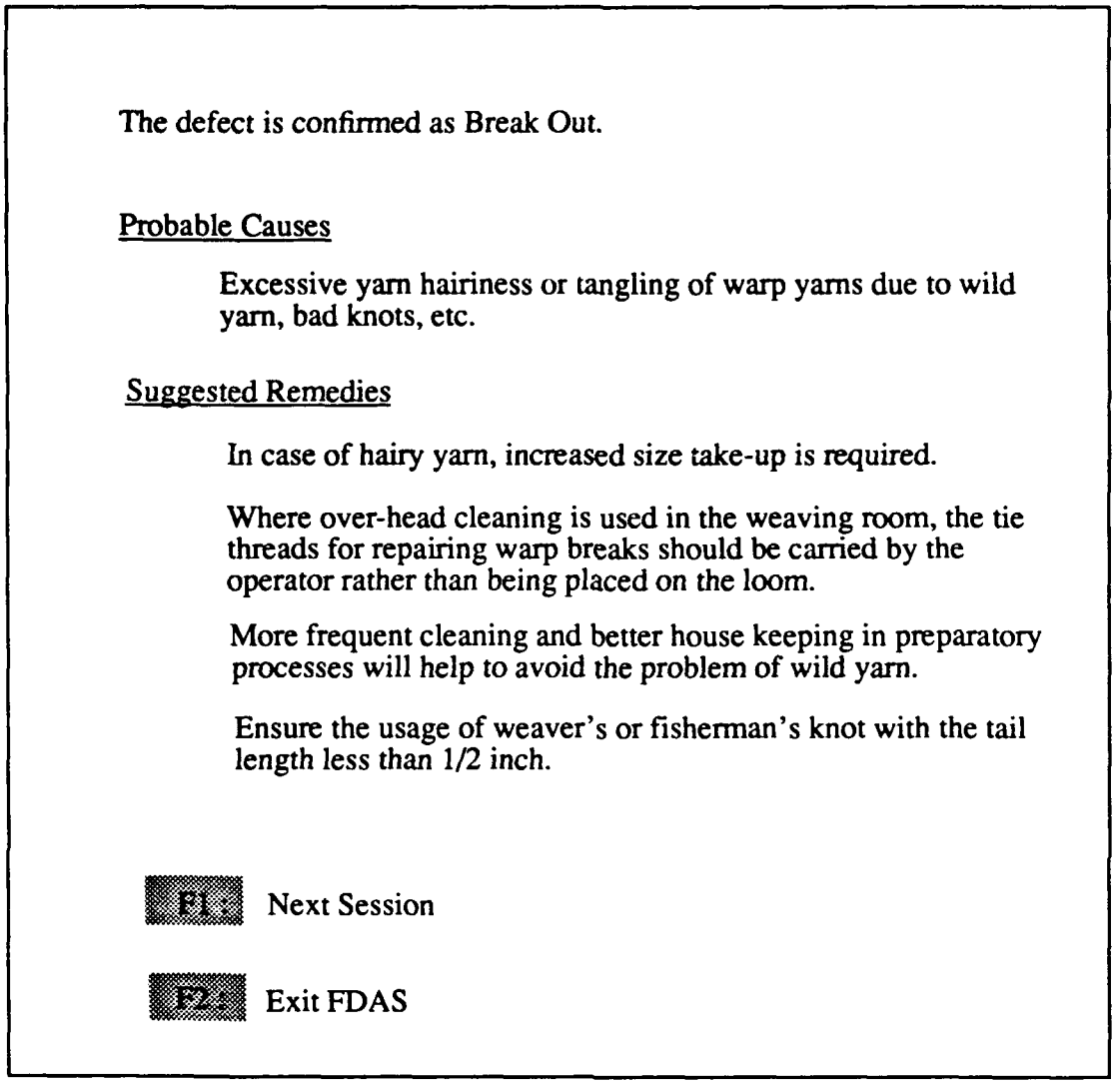

Figure 27. Diagnosis Screen for a Break Out Defect.

By using the down arrow key, the user can scroll down the displayed screen one line at a time or can go to the next page of the file by pressing <PgDn>. The <PgDn> option will show extensions of the diagnosis file, if any.

4. ERROR HANDLING BY FDAS

The user can possibly commit two kinds of errors in describing a defect to FDAS: the visual characteristics of the defect (type, direction, etc.) may not be correctly described (Failure Type 1) or there may be an error in matching the appearance of the defect with the choices provided by FDAS (Failure Type 2). In both instances, FDAS cannot reach a conclusion and will display an error message prompting the user to redescribe the defect. The behavior of the System under these two circumstances is described in this section.

4.1 Failure Type 1

Let's use the example in Section 3.2, where all the steps involved in the diagnosis of a Double End have been described. Assume that the user makes right choices in describing the defect type, direction (orientation), and widthwise pattern but indicates the lengthwise pattern as "Isolated". This is incorrect as the user has already described the direction as "Continuously Along Length". FDAS points out this error to the user in the window shown in Figure 28. The user is shown all the input for verification. The user can start another session and re-describe the defect.

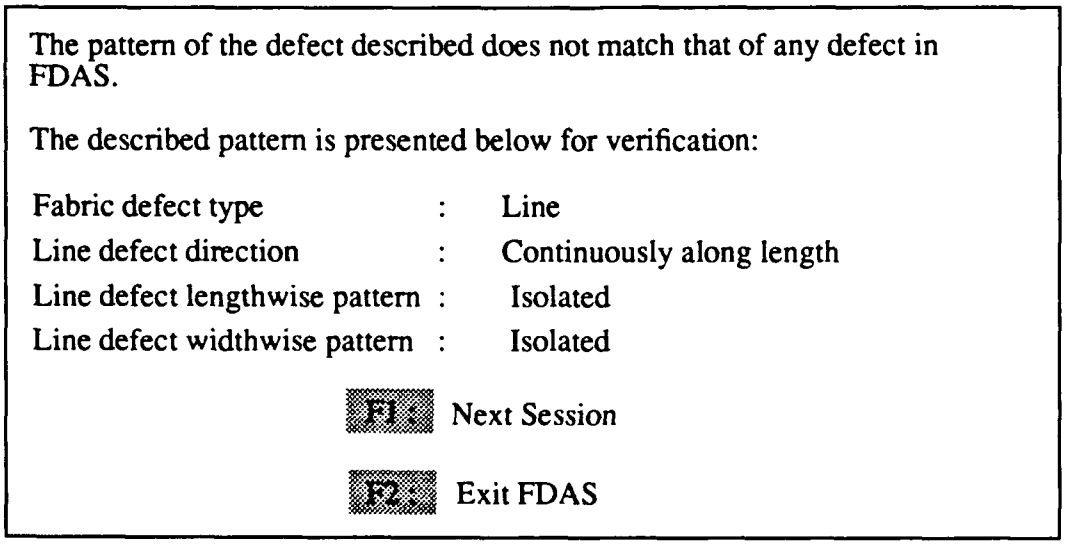

Figure 28. Failure by User to Correctly Describe Defect's Visual Characteristics

4.2 Failure Type 2

In the illustration of Section 3.2, the user rejects the first two defect descriptions presented by the system and accepts the third for the successful completion of the diagnosis.

Now, let us assume that the user does not carefully match the description presented by the system with the actual defect. The user may reject all the descriptions presented. This could also happen if the system has no knowledge about the defect currently observed. In the former case, the defect can be successfully diagnosed by restarting another session and describing the defect carefully. The window shown in Figure 29 is presented to the user to indicate the diagnosis failure.

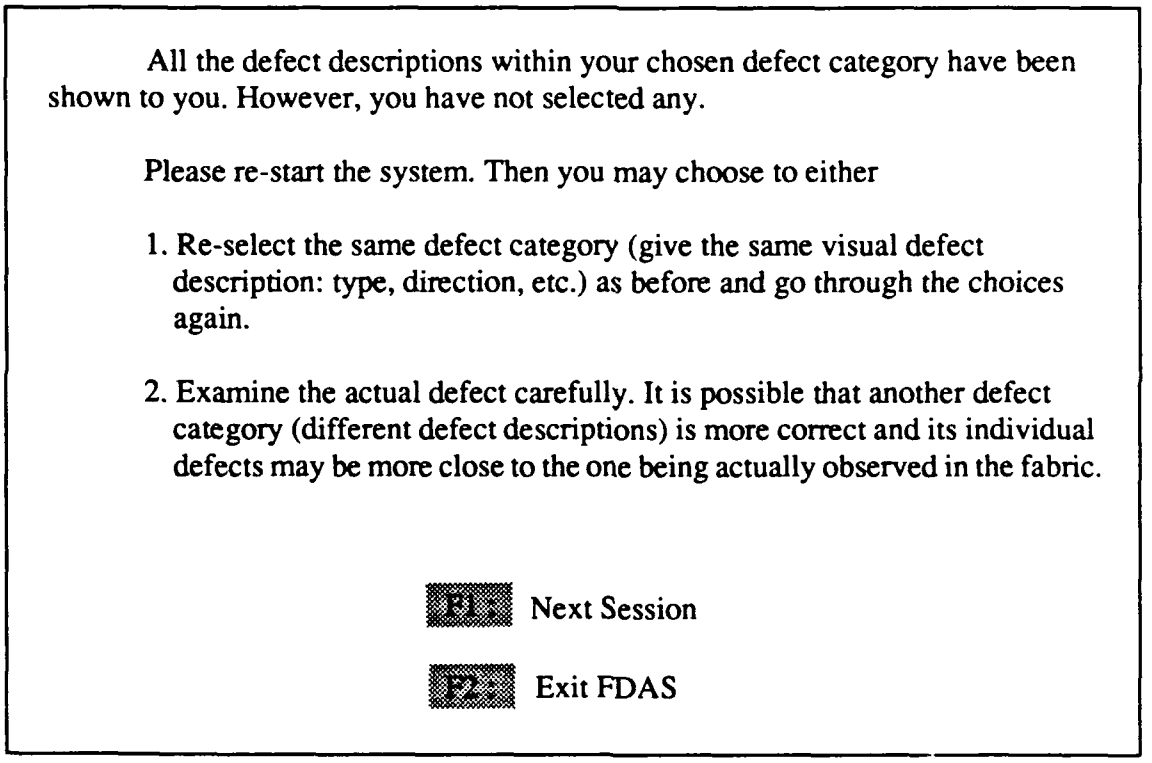

Figure 29. Diagnosis Failure; User Does Not Correctly Match Any Defect Description

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